to appear, however, will be the longest low-temperature lines of the various chemical elements.

Stage 2.—The hydrogen lines will continue to thin out, and the spectra will show many more of the high-temperature lines of different elements. These will differ from the lines seen in stars of increasing temperature owing to the different percentage composition of the absorbing layers, so far as the known lines are concerned.

Stage 3.—With the further thinning out of the hydrogen lines and reduction of temperature of the atmosphere, the absorption flutings of the compounds of carbon should come in.

that its spectrum shows many of the longest lines of iron.

The conditions at this stage of cooling are satisfied by such stars as β Arietis and α Persei. In the spectrum of these stars nearly all the solar lines are found, in addition to fairly broad lines of hydrogen.

There is undoubted evidence of the presence of carbon absorption in the solar spectrum and the spectrum of Arcturus, the only star which has yet been investigated with special reference to this point.

The photographs, then, give us the same results as the one formerly obtained from the eye observations.

Comparison is then made between the groups in the classification first suggested by the eye observations, and the various sub-divisions in which the photographs have been arranged.

II. "On the Velocity of Crookes' Cathode Stream." By Lord Kelvin, P.R.S. Received December 3, 1892.

In connection with his splendid discovery of the cathode stream (stream from the cathode in exhausted glass vessels subjected to electric force), Crookes found that when the whole of the stream, or a large part of the whole, is so directed as to fall on 2 or 3 sq. cm. of the containing vessel, this part of the glass becomes rapidly heated up to many degrees, as much as 200° or 300° sometimes, above the temperature of the surroundings.

Let v be the velocity, in centimetres per second, of the cathode stream, and ρ the quantity of matter of all the molecules in 1 c.c. of it. Supposing what Crookes' experiments seem to prove to be not far from the truth, that their impact on the glass is like that of inelastic bodies, and that it spends all their translational energy in heating the glass. The energy thus spent, per square centimetre

of surface struck, per second of time, is $\frac{1}{2}\rho v^3$; of which the equivalent in gramme-water-centigrade thermal units is approximately $\frac{1}{2}\rho v^3/42{,}000{,}000$. The initial rate at which this will warm the glass, in degrees centigrade per second, is

$$\frac{\frac{1}{2}\rho v^3}{10^6 \times 42 \, . \, \sigma a} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1),$$

where σ denotes the specific heat of the glass, and a the thickness of it at the place where the stream strikes it.

The limiting temperature to which this will raise the glass is

$$\frac{1}{\mathrm{E}} \times \frac{\frac{1}{2}\rho v^3}{42{,}000{,}000} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where E denotes the sum of the emissivities of the two surfaces of the glass in the actual circumstances.

It is probable that ρ differs considerably from the average density of the residual air in the enclosure. Let us take, however, for a conceivably possible example, $\rho = 10^{-8}$, which is what the mean density of the enclosed air would be if the vessel were exhausted to 8×10^{-8} of the ordinary atmospheric density.

To complete the example, take

$$v = 100{,}000 \text{ cm. per sec.}$$

(being about twice the average velocity of the molecules of ordinary air at ordinary temperature); and take

$$\sigma a = \tfrac{1}{8} \text{ cm.},$$

as it might be for an ordinary glass vacuum bulb; and take

$$\mathrm{E} = \tfrac{1}{3000},$$

which may not be very far from the truth.

With these assumptions, we find, by (1) and (2) approximately, 1° per second for the initial rise, and 375° for the final temperature, which are not very unlike the results found in some of Crookes' experiments.

The pressure of the cathode stream of the velocity and density which we have assumed by way of example is ρv^2, or 100 dynes per square centimetre, or about 100 milligrams heaviness per square centimetre, which is ample for Crookes' wonderful mechanical results.

The very moderate velocity of 1 kilom. per second which we have assumed is much too small to show itself by the optical colour test. The fact that this test has been applied, and that no indication of velocity of the luminous molecules has been found, has, therefore, no validity as an objection against Crookes' doctrine of the cathode stream.